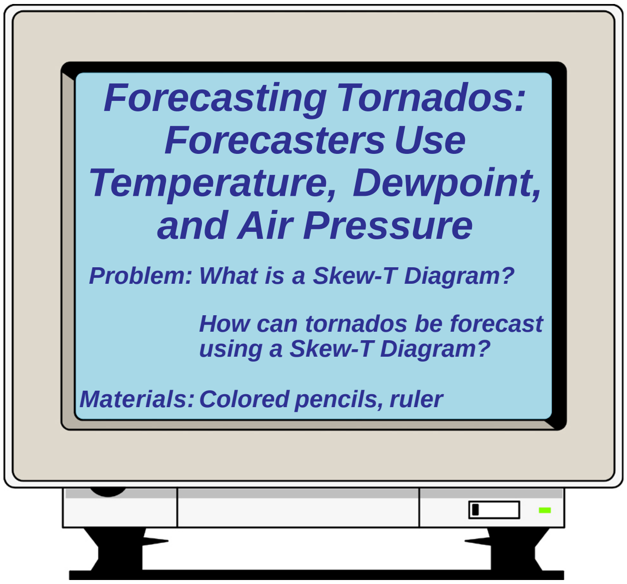


Background

“Early Tornado Warnings Saved Lives on the Plains” exclaimed the headline for the NOAA Report. On May 3, 1999, sixty-six tornados ripped through Oklahoma killing 48 people. Researchers believe that the death toll could have been much worse. One man avoided being hit with an airborne rental truck by just seconds as he and co-workers took refuge from flying debris under tables in the kitchen of a restaurant. Two children and their parents emerged unhurt from a bedroom closet to find their house demolished around them. Based on the amount of damage and a long historical record, researchers estimate that over 700 lives could have been lost.

Yet, despite widespread destruction, early warnings issued by the Storm Prediction Center and the Weather Service Forecast Office in Norman, Oklahoma saved hundreds of lives. The severe weather that was forecasted earlier in the day had put almost everyone on alert.

To issue severe weather outlooks, such as those used in Oklahoma, forecasters use a variety of tools and techniques. In this case, one of the early indications of unstable atmospheric conditions came from a “sounding”. Also known as a Skew-T Diagram, this complicated looking graph provides information gathered from meteorological instruments that are carried by helium-filled balloons high into the atmosphere. The neoprene rubber balloon and its package is called a radiosonde. Over 1000 stations around the world launch radiosondes twice daily. Observations of temperature, dewpoint, and winds at various air pressures are sent back to the launch station by radio. This information is transmitted to the surface, decoded and transformed into a Skew-T Diagram.

The Skew-T Diagram gives a “snapshot” picture of temperature, dewpoint, air pressure, and winds in the atmosphere above a particular point on the Earth’s surface to a maximum of about 16 kilometers above sea level. It is a basic tool used in forecasting not only severe storms, but also daily weather.

On the Skew-T Diagram, the “skewed” horizontal axis slants upward to the right hand side of the diagram at a 45° angle, and is the temperature in Celsius degrees; the vertical axis is atmospheric pressure in millibars. Atmospheric pressure decreases with altitude.

Note: Figure 4.1 gives you basic information on temperature and pressure for comparison with the values you see in this activity.

For Water

$0^{o}C$ = Freezing
$100^{o}C$ = Boiling

For Pressure

A milibar is a unit of air pressure used by the National Weather Service. Examples of atmospheric pressure in milibars:

1013 mb = Sea Level (29.92 inches of mercury)
850 mb = Altitude of Denver
300 mb = Altitude of Mt. Everest

Figure 4.1. Basic Temperature and Pressure Information

Figure 4.2 is a sample Skew-T Diagram. It is an example of a Skew-T Diagram that weather forecasters use. Although it may look complicated, it is easy to figure out. You will understand it better after you follow the steps in the “Procedure” section of this activity.

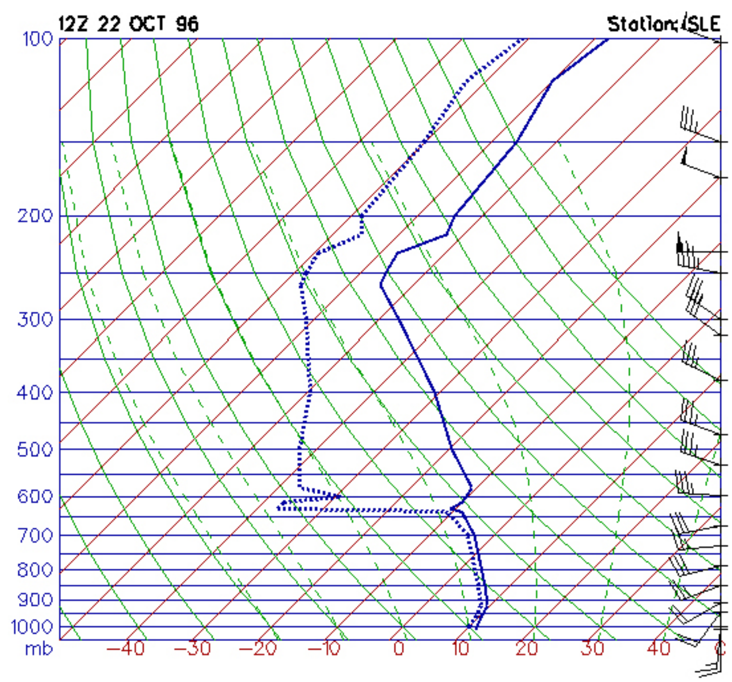


Figure 4.2. Sample Skew-T Diagram

The bold solid line on the right is atmospheric temperature measured in °C. It is plotted using the “skewed” lines on the diagram. These diagonal lines are drawn so that a temperature that cools at a normal rate with increasing elevation will have a bold solid line that is almost vertical. You will plot a similar curve on the template provided in Figure 4.3.

The bold dashed line on the left is the dew point temperature, a measure that indicates humidity. Where the dew point line is far from the atmospheric temperature line, the air is dry; where the dew point line is close to the temperature line, the air is moist. You will plot a similar curve on the template provided in Figure 4.3.

Note: Do not use this Skew-T Diagram (Figure 4.2) for your procedure.

Although Figure 4.2 is <u>not</u> the Skew-T Diagram that was used to help forecast the May 3, 1999 tornados, it is one example of a Skew-T Diagram that weather forecasters use. Notice the solid-line temperature curve and the dashed-line dewpoint curve. Since the dewpoint line is close to the temperature line near the surface, the air is moist and precipitation is likely.

On the afternoon of May 3, 1999, forecasters in Oklahoma noticed an abrupt change in atmospheric conditions based on the Skew-T Diagram. Just prior to the devastating tornado invasion, the Skew-T Diagram showed lots of moisture in the lower atmosphere; however, a temperature inversion provided a barrier to developing thunderstorms.

Suddenly, within one hour, the Skew-T Diagram revealed that the temperature inversion had disappeared. The sky opened to rapid supercell convection as moisture laden warm air swiftly ascended into the atmosphere because of its lower density. At the same time, the Skew-T showed a dramatic shift in wind direction, from southeast at ground level to northwest in the upper atmosphere, fueling a fierce spinning motion. Moisture condensed and tornados were born. Forecasters put everyone on alert.

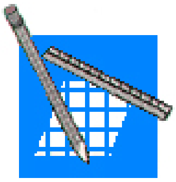
In the past, when meteorologists collected data provided by the radiosondes, they plotted it on charts by hand. Today they use computer software to quickly plot and display this information. Weather forecasters have Skew-T soundings readily available.

Procedure

The Forecast Systems Laboratory in Boulder, Colorado provided the data for this activity.

Note: To help you get started, the first five temperature and dewpoint data points from Table 4.1 are already plotted on the bottom of Figure 4.3. Practice plotting these data points, using Steps 1 and 2 that follow, before going on to the rest of the activity.

1. Using Table 4.1, plot temperature and pressure (in mb) on the Skew-T Diagram in Figure 4.3 that follows this procedure. With black pencil, make a bold, solid curve that stands out.



2. Using Table 4.1, plot dewpoint temperature and pressure (in mb) on the Skew-T Diagram in Figure 4.3 that follows this procedure. With black pencil, make a bold, dashed curve that stands out.

Air Pressure (mb)	Temperature °C	Dew Point °C
967	23	17
927	19	15
909	17	15
852	14	10
820	11	8
795	12	-2
703	5	-15
609	-2	-23
533	-11	-28
500	-14	-35
486	-16	-44
443	-20	-44
418	-24	-37
400	-27	-41
372	-31	-44
343	-36	-43
300	-44	-49
250	-54	
220	-61	
200	-63	
181	-53	
161	-57	
145	-55	
121	-57	
107	-62	
100	-64	

Table 4.1. Pressure, Temperature, and Dewpoint Data for Skew-T Diagram

3. Notice the solid lines that curve upward from the temperature number labeled on the horizontal axis. These lines are called "dry adiabats" and represent how the temperature of dry air would cool if it were lifted or how it would warm if it were pushed down. Outline the dry adiabats in red.

4. Notice the dashed lines that curve upward from the temperature number labeled on the horizontal axis. These lines are called "wet adiabats" and represent how the temperature of saturated (wet) air would cool if it were lifted. Outline the wet adiabats in green.

Note: Temperature cannot warm by moving down a wet adiabat because the air would immediately dry to less than saturated conditions.

Questions

The information that you plotted comes from one of the Skew-T Diagrams that forecasters used to help predict the outburst of tornados on Monday, May 3, 1999, 18:00 UTC (Coordinated Universal Time). Now that you have plotted temperature and dewpoint, you will interpret your graph, much as a forecaster would use the Skew-T Diagram.

Use the information in Figure 4.4 to help you with your interpretation.

SAM II

4-4

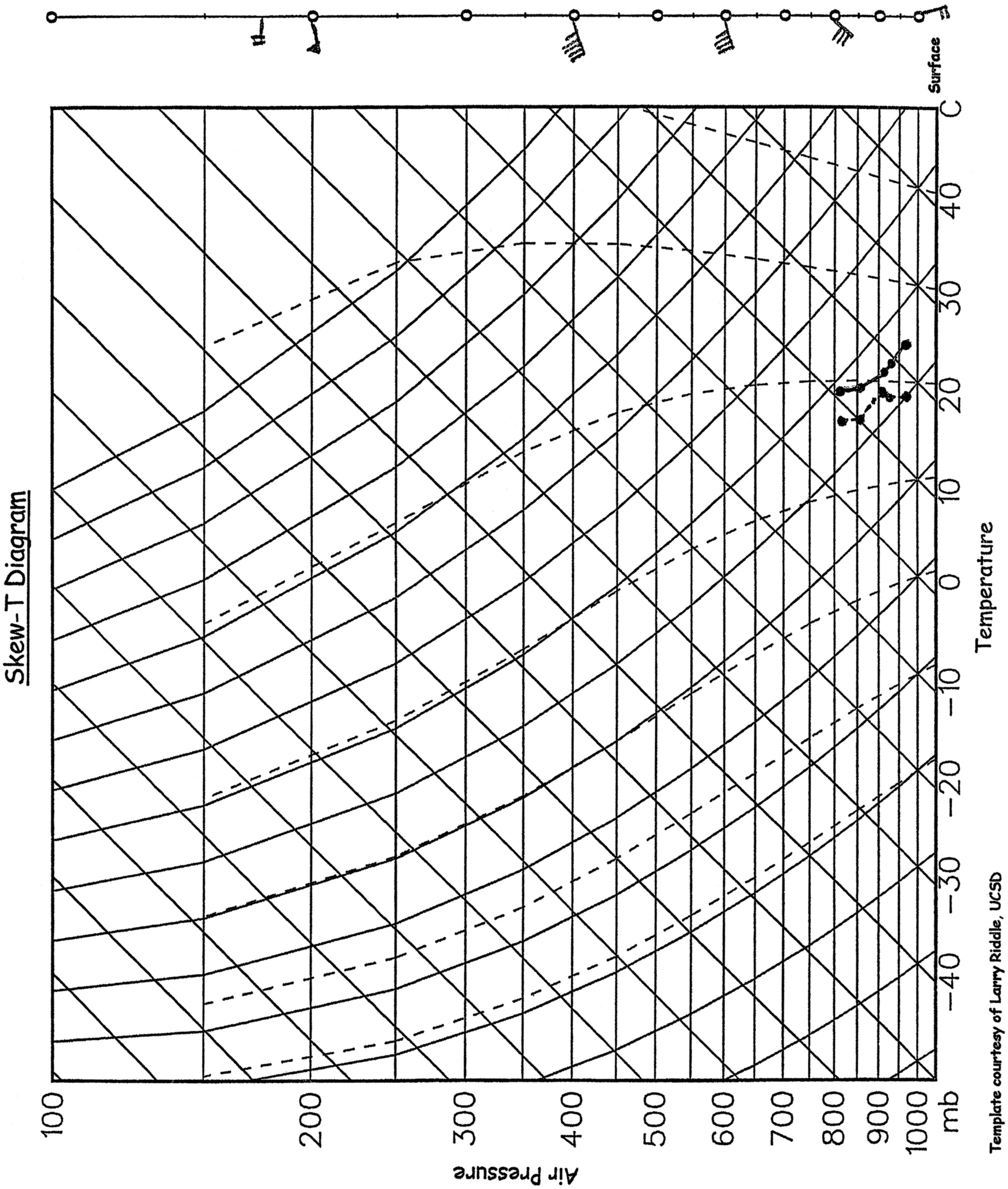


Figure 4.3. Skew-T Diagram Template

FYI

Ideas to Help Interpret your Skew-T Diagram

- Very little moisture is measured above 300 mb.
- Where the dew point line is far from the temperature line, the air is dry: where it is close to the temperature line, the air is moist (forming clouds or precipitation).
- The closer the lines, the higher the humidity.
- Where the two lines overlap, the air is saturated (humidity is 100%).
- When the lines are close or overlapping, clouds are likely to form.
- If a saturated region is thick and close to the ground, it is usually raining or snowing.
- Normally temperature in the troposphere decreases with altitude.
- A temperature inversion occurs when temperature increases as altitude increases.
- Moist air is less dense than dry air.
- If the temperature graph is to the right of the dry adiabat, then the atmosphere is stable.
- If the temperature graph is to the left of the dry adiabat, then the atmosphere is unstable.
- If the temperature graph is either on the dry adiabat line or parallel to it, then the atmosphere is neutral (neither stable nor unstable).

Figure 4.4. Analyzing Your Skew-T Diagram

1. What is the air temperature and dewpoint at the surface (lowest level)?

   ____

   Is the air dry or wet?

   ____

2. What happens to the amount of air pressure as altitude increases?

   ____

3. What normally happens to temperature in the troposphere (lowest layer of our atmosphere that supports life) as altitude increases?

   ____

   ____

4. In this case, what happens to temperature in the troposphere as altitude increases?

5. At what pressure (mb) is the freezing level (0° C)?

6. At what pressure (mb) might there be clouds? (Hint: Give a range.)

7. What happens to the amount of moisture in the atmosphere above 850 mb?

How can you tell?

8. The transition between the troposphere and stratosphere is called the tropopause. If temperature increases in the stratosphere as altitude increases, at what pressure (mb) does the tropopause occur? (Hint: Give a range.)

9. What is the environmental lapse rate between 900 and 800 mb?
(Hint: Lapse Rate = Temperature Change/Altitude Change)

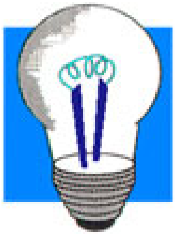
10. Why is there no dew point temperature data above 300 mb?

11. Between which two air pressure points would the atmosphere be neutral (neither stable or unstable)?

12. What happens to the temperature between 820 mb and 795 mb?

What is this weather phenomenon called?

13. Why does an anvil shape (flat top) form at the top of cumulus clouds?
(Hint: temperature)



Conclusion

Review the problem stated on the first page and write a detailed conclusion. Include a diagram as part of your explanation.

FYI

Tornado Safety

The following tragic story was reported in The Oklahoman on May 8, 1999: "*A mother and her son had taken refuge under a turnpike overpass. The mother told her son to hold tight to the girder. As she was holding his hand, the mother could feel the overwhelming force of the wind tugging at her. She let go of his hand so that the wind did not pull him, along with her, into the ravages of the storm. Her son survived and she was not seen alive again.*"

As meteorologists and researchers struggle to improve both short term and long term forecasts, they have also learned several safety-related lessons from the massive Oklahoma tornado outbreak. One tough lesson learned, confirmed that highway overpasses do NOT provide good shelter during a tornado. The bridge and its beams act as a wind tunnel to focus the wind and increase its force.

Knowing and practicing tornado safety saves lives. Remember to heed those weather watches and warnings!

Technology Development in Forecasting

Accurately forecasting weather for more than several days in advance challenges even the most successful forecasting models. Current forecasting would be more accurate if weather data were available from all around the globe. As it is, there are large parts of our world where atmospheric information is not available, that includes area over most of the world's oceans and even over large unpopulated landmasses like the Antarctic.

To help fill the data void areas, NOAA's Forecast Systems Laboratory proposes an innovative system to observe weather conditions. Researchers recommend an observing platform arranged in a grid for every 10 degrees latitude by 10 degrees longitude. In the summer hemisphere, huge balloons would release radiosondes to collect weather data. In the winter hemisphere and near the poles, self-directed aircraft would provide the platform. A platform system would allow measurements such as temperature, dew point, and wind speed to be detected vertically through the atmosphere at many different altitudes. Currently, satellites capture images and general data, but not enough detailed data from atmospheric layers.

Although it would require international cooperation, data similar to soundings used in plotting Skew-T Diagrams would dramatically improve not only weather forecasts, but also forecasts for climate change on a regional scale.